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MKM227 Postgraduate Dissertation

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	Comments	Max Mark	Actual Mark
Introduction *Identification of a valid topic, research question and objectives framed to Masters Level standard with academic rationale developed, clear industry contextualisation of the research topic*	**Supervisor Comments:**	**10%**	
	2nd marker Comments:		
Critical Literature Review *Depth and breadth of literature search, engagement with seminal authors and papers, evidence of a critical approach toward the scholarly literature*	**Supervisor Comments:**	**25%**	
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RISK EVALUATION AND MITIGATION IN DOMESTIC PHOTOVOLTAIC PROJECTS

According to the UK Climate and Policy

A dissertation submitted in partial fulfilment of the requirements of the Royal Docks Business School, University of East London for the degree of **MSc Project Management**

September 2013

14,453 words

I declare that no material contained in the thesis has been used in any other submission for an academic award

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RISK EVALUATION AND MITIGATION IN DOMESTIC PHOTOVOLTAIC PROJECTS

According to the UK Climate and Policy

Milad Atigheh Chian

U1223705

September 2013

Abstract

The energy supply is one of the major issues in the world. In today's fast-pace world the huge need of energy is driving force to move from fossil fuels towards renewable energy. Solar energy as one of the renewable energy source can help to shift to this kind of energy.

In every project, there are some uncertainties and risks that can impact the result. Identify and evaluate PV projects' risk can assist these project towards a better result. For this purpose, having strategies to cope with these risks during the lifecycle of the PV project can be beneficial to lead the project towards success.

This research tried to evaluate the rate of the risk in the photovoltaic projects and after that investigate which measures and strategies can help this kind of projects to mitigate possible risks according to the UK climate and policy. For this purpose, a quantitative research method was employed to collect required data and information. A descriptive data analysis method chose to analyse collected data to interpret the result.

The gathered data shows the major problem in the PV projects is associated with financial issue that increases the risk. After that installation and operation phase of a PV system has the highest rate of the risks. Also the result indicates the appropriate strategy to control risk is to put the risks on other party in the project. It means government, banks, and insurance beside the expertise of the solar company can play a prominent role in the PV projects.

Acknowledgements

The writing of this dissertation was a challenge that the support, guidance, and the patient of the people who co-operated in this research made it easier and without their helps this study would not have been completed and I should thank them:

- Dr. Manish Unhale, my supervisor who his knowledge and experiences in research helped me to carry out this study.
- My parent who are the biggest supporter in my life and without their support I could not find my way.
- All the solar experts that responded to the questionnaire by patient and interest.

This dissertation is dedicated to Sarah and to all my family.

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The energy supply is one of the controversial issues in today's world. Increasing use of fossil fuels (i.e. oil, gas, and coal) caused a lot of problems. Environmental pollution is one of the consequences of using this energy sources. Other noteworthy point is that sooner or later these sources of energy will run out and having a plan for replacing these sources with renewable energy sources should be considered.

With the increasing use of renewable energy in the world, the UK government decided to use these sources more than the past. The "Department of Energy & Climate Change" has published the renewable energy scenarios to 2030. They try to achieve this aim to supply 15% of the energy demand in the UK from renewable energy sources by 2020 effectively and cheaply. This achievement includes solar energy too (Department of Energy & Climate Change, 2011).

Solar energy as one of the renewable energy sources can be a proper replacement for fossil fuels. According to Nadimi & Atigheh Chian (2011), solar energy has some advantages that are significant:

- ✓ Clear: there is no pollution during the process of the converting solar radiation into electricity.
- ✓ Unfailing: the sun radiation will remain for millions of years and there is no worry about the source.
- ✓ Free: this is completely free. No payment for using sun radiation and sunlight can use everywhere freely and easily.
- ✓ Accessible: the sunshine are available everywhere. Some countries depends on their geographical location have solar energy more than other places, but it is accessible everywhere.
- ✓ Safe: there is no harm in converting solar energy. No chemical harm and no danger in converting process.

One of the applications of the solar energy is photovoltaic system. This is a technology that directly converts sunshine into electricity by a tool that named PV modules or panels. One type of this technology is Building-integrated Photovoltaics (BiPV) which use in building to generate the required electricity for all or some parts of the daily residents demand. The building remains connected to the national grid and the system has this ability to export generated electricity to the grid (Prasad and Snow, 2005).

1-1 Research's Objectives

Due to the increasing interest in using of photovoltaic systems and the government supports, many companies encourage owners to use this technology to generate their own electricity. Hence, having a framework to implement the projects is necessary to lead the project towards success. Implementation of every project needs a framework to cope with probable difficulties and problems that may occur during the project. The PV projects also have their own framework that the project managers follow them to implement the project successfully.

Having an appropriate practice in design, installation, and operation of the PV projects is a crucial point that in all aspects of the project it should be considered.

According to Project Management Body of Knowledge (PMBOK, 2004) risk is one of the factors that can influence the success of every project. Risk can occur during each phase of the design, installation, and operation. Project risk management is the process of identification, analysis, and response the risks that may happened in every part of the project.

Nowadays, the interest of investing in the renewable energy projects especially PV systems increased, so the risks are on the rise. Regulatory risks, technical risks, and financial risks are such uncertainties that may happened during each phase and risk management strategies including expertise, technical data, and financial insuring measures can protect project against them (Economist Intelligence Unit, 2011).

In this research we try to follow this process in order to identify photovoltaic projects' risks and try to specify the measures and strategies that can help to mitigate the risks according to the UK climate and regulatory. Therefore, this study includes two parts. To implement a successful project, a framework is needed to progress the phases of the project and lead that towards success. The PV projects have a framework that is almost same in all BiPV projects. At the first step, we try to identify the rate of the possible risk that may occur during the PV projects' phases (i.e. design, installation, and operation) and then we try to look into measures that can help to mitigate the risks.

1-2 Research's Questions

In order to achieve the objectives of the study, two questions designed that answer these two questions can satisfy all the goals of this research. It is noteworthy to mention, this research is not a heurist one. It tries to use literature and research beside the primary data collected from relevant companies and experts to accomplish the objectives of the study. In this chapter, the questions are introduced to indicate the aims of the research and help to make objectives more clear.

- ✓ In the process of the implementation of a PV project, which phases are more risky?
- ✓ What measures should be employed to control and mitigate the risks of the each phase?

In order to evaluate and investigate the rate of risks in the PV project's phases, the first question was designed. Each phase during the process of the PV project is related to a task from prefeasibility studies to end-life and decommissioning. Each phase involves in some risks such as technical, financial, and policy risks. It would be beneficial that try to evaluate the risk of the each phase and investigate that these phases are high or medium or low risk. It can help to have a real image of the situation and understand which of them are more important and have priority.

The second question was designed in order to meet the next objective of the research. After identify which phase in the PV process is more risky, the next measure is to find some measures to mitigate the risk. There are many strategies (i.e. insurance, warranty, finance, etc.) that project managers employ to control the risks in the project. Investigating which one is more practical and can control the influence of the risk on the PV project is the duty of the second question.

1-3 Research Structure

In this section a brief outline of the research states. In the next chapter "Literature Review" the previous research and literature will review to critically evaluate the studies that carried out on the same topic. Some research undertook related to renewable energy and solar energy in the UK and outside especially in the United States that evaluate them can help to understand what measures were considered and what gaps are still remain in this topic.

The major problem or gap in these studies is that most of the research is related to the renewable energy whereas doing a research specifically associate with solar energy and photovoltaic systems is necessary. There is some research relevant to solar energy, but most of them carried out in the United States according to its climate and policy.

After that in the chapter three "Methodology", we will talk about research method. We will re-state the research question according to the gap which mentioned in the "Literature Review Chapter". Then we talk about the research design include the method of the research, data collection method and tool.

The research limitations and obstacles play a major role in the choice of research approach (Strube *et al*., 1985). There were some limitations during carrying out this research such as short time of research and companies' privacy policy that influenced the research method. These obstacles will be mentioned in this chapter in order to examine the limitations.

At the end, we will mention the data analysis approach and explain about the process of the data collection and analysis.

The chapter four is “Data Analysis”. This chapter will sort the gathered data by relevant software (Microsoft Excel 2010) according to the data analysis method that was chosen before. This chapter as the most import part of the study present the result and interpret the collected data. At the last part of the chapter, the result will compare with previous research to find any similarity or differences and contrast in findings and evaluate the result.

The last Chapter is “Conclusion and Recommendation”. In this chapter will try to answer the question according to the finding and recommend an appropriate solution for the problem according to the result of the collected data.

1-4 Summary

The chapter started with expressing the significance and necessity of using renewable energy and especially solar energy.

In this chapter the objectives of the research was introduced and the questions were mentioned and the reason of the designing these questions was explained. The structure of the research and its chapters stated in brief to give a clear image of the process of the study.

Chapter 2: Literature Review

2-1 Introduction

This chapter tries to critically review the other literature in renewable energy and photovoltaic systems. Risk as the key factor in every project can have adverse impact on PV projects too. With the increasing proliferation of using solar energy and PV systems, the significance of having a project management framework for such projects becomes more and more evident. According to Project Management Body of Knowledge (PMBOK, 2004) time, cost, quality as main purpose of each project management team beside other criteria (i.e. risk, scope, benefit, etc.) should be considered in all projects including PV projects. Building-up a PV system installation needs several phases and preliminary study in order to confirm the reliability of the project.

Risk as the influential factor in the PV projects should be considered in all part of the project. Having an effective risk management strategy in the PV projects' lifecycle can assist to achieve the objectives of the project. In order to achieving this goal, evaluating the risks' rate in the project's lifecycle can be beneficial to control and mitigate the influence of the risk on the PV projects. Identifying risks and their rates and also the influences on the project can help to find an appropriate strategy to mitigate the effects.

2-2 PV Projects' Framework

As mentioned before, the project management framework plays a major role in the success of the project. PV projects have their own frameworks to control the process of the project. Many frame works can use in PV projects that two of them will be mentioned following. These frameworks chose as a sample of many frameworks that are used in this kind of projects.

An overview of project lifecycle for a PV project was shown in Figure 2-1. It shows consideration of the PV system before the start of the project, during implementation and installation, maintenance, and legacy stage (A-Sun Energy, 2011).

Figure 2-1: The overview of the PV project lifecycle

This PV project cycle has eight phases or steps that each of these steps is allocated to a task in order to control the process of the project step by step. "Pre-feasibility study" is related to the analysing the site location, weather conditions, etc. to understand that the location is a suitable place for installing a PV system or not. After that according to the collected data from the site in the next step "Photovoltaic system design", the system component design to have the maximum efficiency. The next step "Business plan" makes a comparison with the site features and designed system to clarify that the project is profitable or not. "The permission planning" is the next step to obtain the necessary permits depends on the local planning authority. "Selection of suppliers" and "Installation" are the next phases that are related to the choosing an appropriate solar company and allocate tasks to them for system installation. "Management of the installation" is a phase that manages the system in terms of operation and maintenance. The last phase is "End-life of the Installation". This phase decommissions the system

equipment. This action can happen after 25 years of the system and is related to the system recycling (A-Sun Energy, 2011).

Although it is not the sole project framework of PV systems, but most of the studies use the almost same approach. Following these approaches have a direct bearing on the project and can lead PV projects towards success. Identify risk in pre-feasibility study step; monitoring and controlling the risk during the lifecycle of the PV project can help the project to be successful. Another overview process can be observed bellow (Rudkin & Thornycroft, 2008). This framework has eight steps that start with "Outline design" and finishes with "PV operation and maintenance":

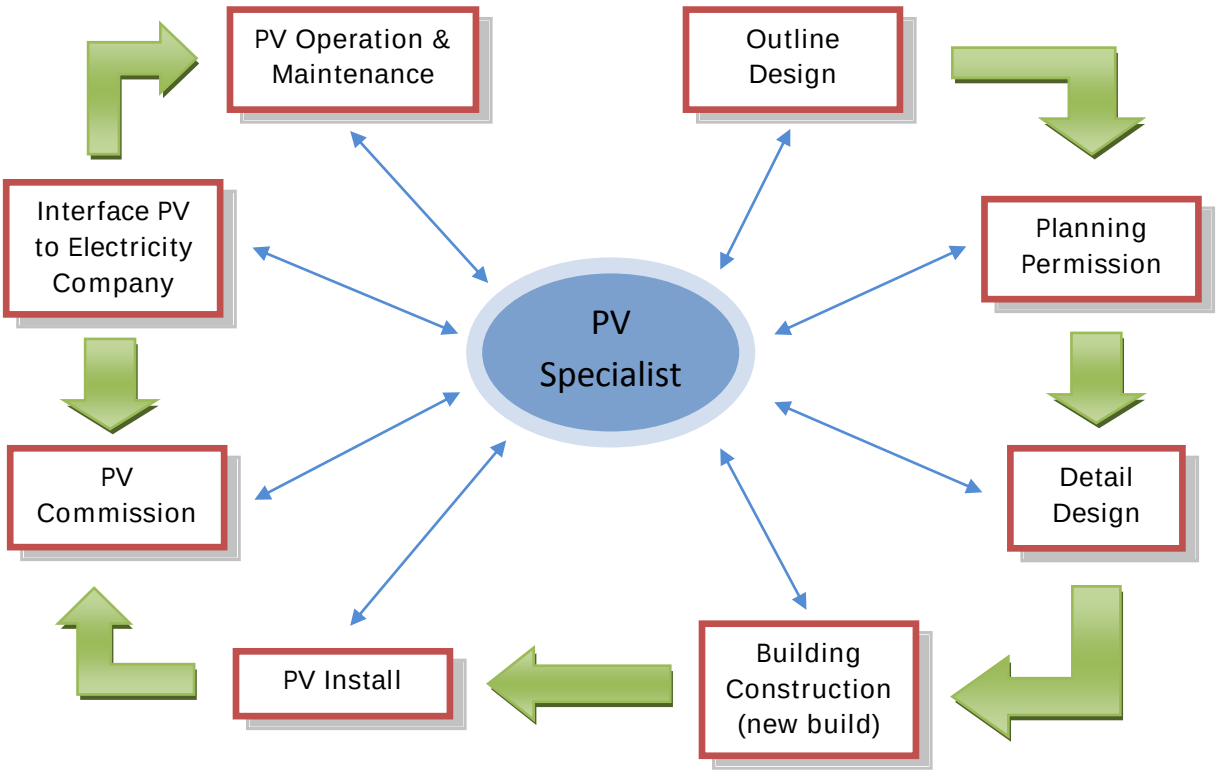

Figure 2-2: Project's process overview

It is clear that these two processes are nearly similar to each other. Although the second framework has more details rather than the first one but the problem which is common in both of them and also in the most frameworks is that the risk identification and mitigation did not mention in these projects' process.

All in all, a PV project process can be divided into following steps:

- ✓ Planning and designing phase
- ✓ Business plan and financial issues
- ✓ Permission and regulation phase
- ✓ Installation and testing phase
- ✓ Operation and maintenance phase
- ✓ End-life and decommissioning phase

This frame work can cover all measures that should be considered in the lifecycle of a PV project.

As mentioned, the major problem of these two processes is that the risk is not considered sufficiently during lifecycle of the projects. They did not mention risk whereas it is one of the influential parameter in every project. Identifying risk in pre-study phase of the PV project and monitoring during the project can help to control and mitigate the risk.

2-3 PV projects' Risks

According to a survey conducted by the Economist Intelligence Unit (2011) the overall percentage of risks associated with each of the above stages in renewable energy projects shown in Figure 2-3:

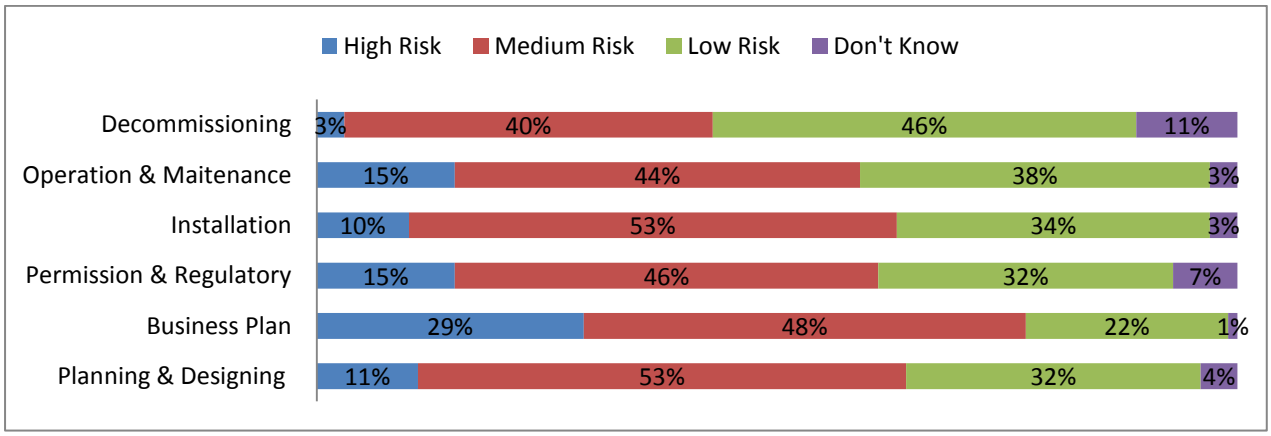

Figure 2-3: The overall percentage of risks related to the PV projects steps

Although this diagram can make a good image of the risks related to the renewable energy projects and can clarify the interest of each steps, but the

problem is that this statistics is about all types of renewable energy project and does not specify anything relevant to photovoltaic projects.

It is obvious that all the phases evaluated as medium risk (except decommissioning phase). It makes the significance of the risk management more clear.

2-4 PV Project Risk Management

Risk management is the process of planning, identification, analysis, responses, and monitoring and controlling risks during a project. The main objective of this process is to reduce the probability of the events that can have adverse impact on the project's result (PMBOK, 2004).

There are myriad types of risk management strategy in the PV project lifecycle. A typical risk management strategy for the PV projects is shown in Figure 2-4. This strategy is divided into three segments: (1) identify risks (2) mitigate risks and allocate them among related project's parties (3) insure the risks that cannot be efficiently absorbed by the parties. In this part strongly recommend that this measure is assigned to the third party (insurance companies) (Travis *et al.*, 2013).

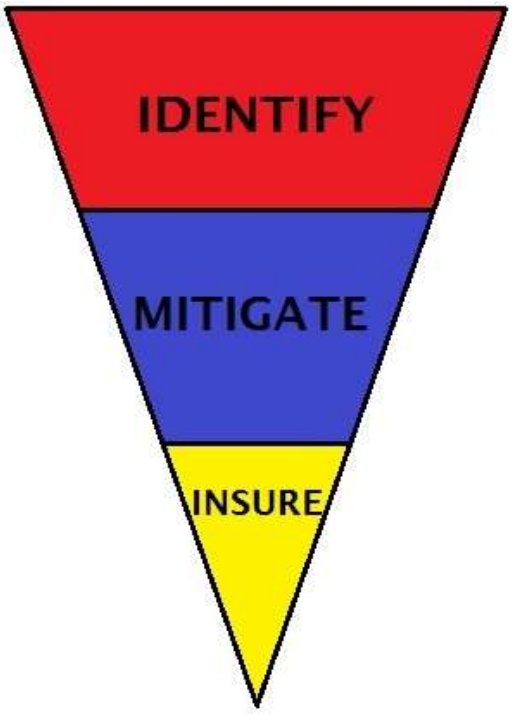

Figure 2-4: The risk management strategy for the PV projects

2-4-1 Risk Identification

Risk identification establishes the risks and their impact on the project. This measure should take before starting the project and iteratively during the project cycle to identify new probable risks and their influence on the project (PMBOK, 2004). It means risk in the PV project should identify in pre-study step and try to monitor probable risks during lifecycle of the PV project.
According to Aragones- Beltran *et al.* (2009) fifty risks were identified related to the PV projects and categorised into eleven categories. These risks are relevant to solar plants, although it can be extended to the domestic photovoltaic projects:

- ✓ Political risks
- ✓ Technical risks related to the plant site
- ✓ Technical risks related to the photovoltaic technology
- ✓ Economic risks related to the plant exploitation
- ✓ Economic risks related to the obtaining of the plant start-up permits
- ✓ Economic risks related to the plant site
- ✓ Economic risks related to the photovoltaic technology
- ✓ Macroeconomic risks
- ✓ Time delays
- ✓ Legal risks
- ✓ Social risks

Political risks are associated with the policy and regulatory that governments have in order to support renewable energy projects. Changes in the policies can increase the rate of risks in the projects.

There are some technical risks which are relevant to the system's technology and exploitation. The technology has a crucial role in the efficiency of the PV system Lack of appropriate technology and exploitation are other reason

that can cause risk. Also there are some other risks (i.e. economic, time delay, etc.) that can influence the PV projects.

Five categories of eleven categories associated to economic and financial issues that can show the importance of financial risks in the PV projects. Some of the fifty types of risks that divided into above categories are:

- Changes in the government energy policy and regulatory
- Equipment thefts
- Revenue estimates based on effective solar radiation time
- Delays in the obtaining of the Local Body Approval
- Costs due to lack of consistency in solar tracker selection
- Performance losses
- Flood prevention works
- Changes in the general legislation
- Delays in the signature of the agreement with the electricity supply company
- Vandalism
- Delays in the obtaining of the plant start-up act
- Plant operation costs
- Changes in the specific legislation
- Earthworks resources
- Changes in energy prices
- Obtaining of the registration in the register of production facilities in special regime
- Obtaining of the construction license
- Corrective maintenance costs
- Legislative changes in the Plant Start-up Act
- Costs due to wrong selection of PV cell
- Development of new PV solar power systems

These detailed risks are more relevant to the solar plants and some of them never happened in the domestic PV projects. On the other hand, this research carried out in Spain. Although these identified risks can be

generalised to any other countries, we should not lose sight of the fact that every country has its roles and climate.

According to Environmental Due Diligence (EDD) Of Renewable Energy Projects (2008), most of the risks in the solar projects are related to the following characteristics:

- ✓ Information availability (e.g. weather data analysis)
- ✓ Environmental impacts (sun, wind, etc.)
- ✓ Probability of occurrence
- ✓ Mitigation/compensation measures

The point is that this survey conducted in associated with solar thermal energy. Although the mentioned risks are in the PV projects too, but the interest of the each risk may be different from solar thermal energy.
United Nation Energy Programme (2004) believes that most risks are related to component breakdowns, weather damage, theft and vandalism.
There is another categorisation for identified risks related to renewable energy projects that is suggested by United Nations Environment Programme (2004):

- ✓ Cognitive risks: the risks associated with the low level of awareness and understanding of renewable energy.
- ✓ Political risks: the risks related to policy, rules, and regulatory.
- ✓ Analytical risks: these risks are related to the accessibility and quality of information.
- ✓ Market risks: the risks relevant to lack of financial, legal framework in order to support project.

Travis *et al.* (2013) carried out a survey related to the risk management in PV projects. This research provided an overview of the PV projects risks. It divides the PV risks into two main categories: technical risks and non-technical risks. Both of these categories are subdivided into two parts: development risks and operational risks.

Technical Risks during Project Development

The first steps in the renewable projects are more risky. Land acquisition, permission and approvals, weather data collection, etc. are such measures that are in the technical development category. Financial tasks are other primary measures with high risk that are not in this category (Economist Intelligence Unit, 2011).

The technical development risks can be observed in "Installation and testing phase" and "Planning and designing phase" that has various aspects of system design, resource estimation and validation, siting evaluations, and grid interconnection. Identified following technical development risks can cause adverse conditions during the PV project cycle. Each of these risks may have potential damage or loss for the project (Travis *et al.*, 2013):

- ✓ Resource Estimation: a wrong estimation in the amount of sun radiation can increase the risk.
- ✓ Component Specifications: solar panel, inverter, wires are some parts of a photovoltaic system that the quality of them have impact on the system efficiency.
- ✓ System Design: any mistake in the design of the system and its components can put the project in risk.
- ✓ Performance Estimates and Acceptance/Commissioning Testing: overestimate the PV system's output increases risks.
- ✓ Site Characterisation: geographical location, climate, surrounding buildings and trees, etc. run the risk.
- ✓ Transport/Installation Risks: any careless in the equipment transport or installation can damage the equipment and increase the rate of risk.

Technical Risks during Project Operation

The major risk during the operational phase is related to the uncertainty of energy production. If the project performance does not meet the estimated revenue, the project will generate less income from power sales and the sponsor or investor may experience difficulty in servicing its debts or earning its investors their returns and the project would face financial risk (Travis *et al.* 2013). This type of risk can be observed just in "Operation and maintenance phase". This category includes two risks (Economist Intelligence Unit, 2011).

- Operations and Maintenance Risks
- Off-Taker Infrastructure Risks

Fthenakis *et al.* (2006) classified the risks during operation to accidental routine during operation, accidental severe risks, and difficult to evaluate risks. All of these risks have consequences that affect the efficiency of the PV systems. Accidental routine are high frequency with low consequences unlike, accidental severe are low frequency with high consequences. Difficult to evaluate risks subject to, and sometimes reinforced by perception.

Non-Technical Development Risks

Policy risks have the highest place between non-technical development risks and any development in PV solar power systems and new technology can have the lowest risk during development of the PV project (Beltrán *et al.*, 2009). Policy and regulatory associated with government support and protection for renewable energy. This support can help the PV projects to become viable economically and change in regulatory and policy may put projects in risk (Economist Intelligence Unit, 2011).

Travis *et al.* (2013) identified nine different subcategories of non-technical development risk. Two of the largest them are microeconomic and regulatory environment that can influence the development in the given year. They

mentioned that insurance against regulatory risks is not available in the United States market, although it would possible to legislate for this issue.

The remains non-technical development risks that can affect the PV project enumerated below:

- ✓ Transmission/Distribution and Interconnection
- ✓ Developer Risk
- ✓ Power Purchase Agreement and Pricing
- ✓ Construction Risks
- ✓ Policy/Regulatory Risks
- ✓ Insurability
- ✓ Site Control
- ✓ Multi-Contracting Risk
- ✓ Commodities Risk

Non-Technical Operational Risks

The last segment of the PV project risks is non-technical operational risks. Unlike the technical operational risks, it is not related to the project's power production. The following non-technical operational risks are associated with a project ability to sell power and maintain its economics throughout its lifetime (Economist Intelligence Unit, 2011):

- ✓ Credit/Default Risk
- ✓ Power Purchase Price Risk
- ✓ Off-Taker Risk
- ✓ Duration of Revenue Support
- ✓ Insurance
- ✓ Weather and Resource Risk

The third important risk in renewable energy projects is weather and source risk. This type of risk is more acute for wind and hydropower projects than for solar. Solar radiation levels typically deviate by no more than 4% from normal levels, nevertheless this amount can influence on the PV projects. Weather risk can have two types of effect on the renewable energy projects.

The first one is that the real output becomes less than estimated output and subsequently the revenue comes below too. The second probable adverse impact of weather risk is that the variations of revenue and output can create volatility of earnings year to year and threaten the economic viability of renewable energy projects.

2-4-2 Risk Allocation and Mitigation

After identify the risks during the lifecycle of a PV project, the second measure in the PV risk management strategy is risk mitigation and allocation. Because of many tasks in development process of the PV projects, it would be worthwhile to understand which task associate with which risk and which measure can help to control which risk. Clear contracts and specified responsibilities are such measures that can help to place a claim if losses are incurred (Garcia and Lopez, 2012).

According to Economist Intelligence Unit (2011) the following chart in Figure 2–5 can show the major measures for risk mitigation in the renewable energy projects:

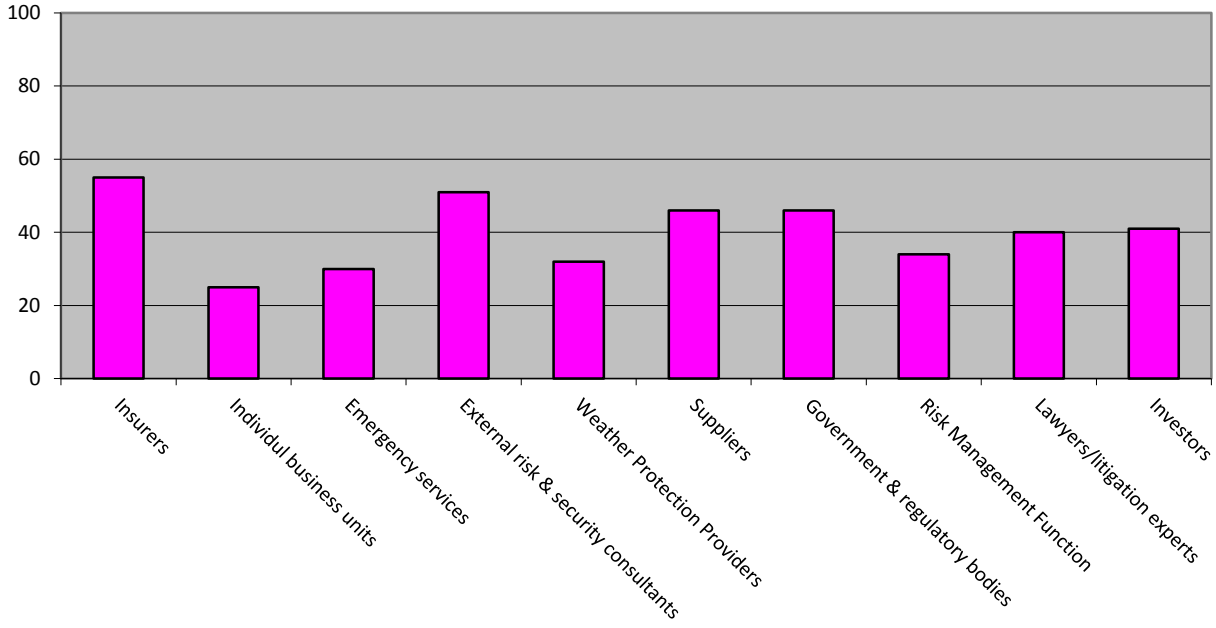

Figure 2-5: Risk mitigation strategies in renewable energy projects

The chart indicates that project managers in order to control and manage risks rely on outside support heavily. Insurers, external consultants, government agencies, etc. play a prominent role to help manage the risks. The reason of this measure is that most of solar energy companies do not have an appropriate body of technical expertise within their firm and they have to import the expertise. It can happen by outsourcing. In order to mitigate environmental, political and regulatory risks related to renewable energy projects following measures are beneficial (Economist Intelligence Unit, 2011):

- ✓ Environmental audits improvement
- ✓ strict environmental standards implementation
- ✓ Frequent and detailed communications with policy makers, regulators and industry bodies
- ✓ Frequent and detailed communications with media, consumers, and environmental groups
- ✓ Adopting stricter monitoring of sub-contractors' environmental practices
- ✓ Seeking redress from governments for the impact of adverse policy decisions

Since 2000, the UK government started to support photovoltaic in three methods: R&D funding, demonstration programmes, and market stimulation. Market stimulation is a programme that provides a guaranteed price for generated electricity in England, Scotland, and wales. For each kilowatt of electricity that is generated, a specific amount pays to the owner (Great Britain. House of Parliament, 2012).

Beyond environmental, political and regulatory risks, most of the renewable energy companies try to mitigate financial and market risks. The following measures are taken to control financial risks (Economist Intelligence Unit, 2011):

- Protecting against financial losses related to the power price fall

- Improving legal and regulatory compliance to ensure continued access to financing
- Improving corporate governance practices and policies to ensure continued access to financing
- Adjusting the company's capital structure to ensure access to capital at a reasonable cost
- Protecting against the inputs price rise
- Protecting against adverse weather conditions and the resulting fall in volume of electricity produced
- Diversifying the customer base to reduce market risk

These actions actually help PV companies to protect themselves against financial losses that may encounter during their projects. The objective of this research is to investigate the measures that can hedge the own project against risks. Nevertheless, some of these strategies can help the project against financial risks too.

In the financial structure of a renewable energy, the benefits and financial risks of this kind of projects are allocated to the various owners such as investors and lenders (if there is any debt or loan at the project). These benefits include tax benefits and cash benefits, both of them are allocated based on the ability of the investors to utilise them. The United States' solar project finance structure is designed to maximise the value of the tax benefits that is offered by the federal government and relevant state government, if applicable (Travis *et al.,* 2013).

Other types of risk that should be considered to mitigate are operational risk and construction risk. Following strategies are such measures that can help to control and mitigate relevant risks (Economist Intelligence Unit, 2011):

- Selecting proven construction's technology
- Having a regular equipment maintenance plan
- Employees training and recovery plans testing
- Investing in R&D
- Improving market data analysis

- Improving supply chain management
- Having an improved monitoring system record industry and market trends
- Weather data analysis
- Improving scenario planning
- Adjusting the strategic business mix on an on-going basis

Choosing an appropriate project site can assist to mitigate risks. Amount and quality of the energy resources (sun radiation), frequency of unexpected events (e.g. storm and floods), and access to transmission are the major factors that increase risk. Selecting a site with above criteria leads project towards a low risk conditions especially in terms of financial issues. The majority of the photovoltaic projects' costs are related to PV modules or panels. In addition, these panels are the actual revenue-generating components of a PV system, thus choosing a suitable manufacturer and module (proven technology) have prominent role to control and mitigate relevant risk (Travis *et al.,* 2013).

United Nation Energy Programme (2004) believe, in order to control technical problem and component breakdowns, a good performance guarantee can control the consequences of technology risks.

Solar companies do not normally have construction service. Hence, a construction party should add to project to implement construction parts. Pay enough attention to choose suitable EPC help to complete the PV project on time, within budget, and according to the specifications of the project. With this approach, the construction phase risks can be mitigated. Independency of engineers is another noteworthy criterion. Independent engineers typically do not take on any project risk (Travis *et al.,* 2013).

In order to collect weather data at location and reduce the relevant risk, Garcia and Lopez (2012) suggest following measures:

- ✓ Prepare a good ground measured irradiation data at least for six months and ideally one year in order to understand the seasonal variability of solar irradiation.
- ✓ Gather satellite derived data from reliable sources for more than 10 years.
- ✓ Compare ground data and satellite data in concurrent period to remove inherent bias related to satellite data.

As previously mentioned, there is literature on identify and mitigate risks in the UK that is related to all types of renewable energy; but project managers need to find PV project risks and specify their approach to cope with uncertainty and risks that happened in this kind of projects.

Another issue in the literature is that most of the previous survey carried out in the United States. There are many parameters in the PV projects such as financial issues, environment and weather, policy and regulatory that may totally vary from country to country. Evaluating and mitigating risks in the UK with different climate, policies, regulatory, etc. exactly relevant to PV projects is the objective of this survey.

2-4-3 Insurance

Insurance is the last step after identification and mitigation in the PV project risk management strategy. It is about the insurance companies that can help the PV projects to cover their loss. As mentioned before, sharing the risks between all project's parties can help to control the losses and consequences. The insurance companies are one party that can accept the risks influences and control the consequences. It is not associated with the objectives of this research and we will not discuss about that.

2-5 Summary

In this chapter, we discussed about literature relate to the strategies that should be employed in order to control the risk in the renewable energy projects and photovoltaic projects.

Risk identification and mitigation were the main points of this chapter. Identified risks that other studies were stated critically were reviewed and the measures that can help to control and mitigate them were considered.

Chapter 3: Research Methodology

3-1 Introduction

The main purpose of this chapter is to examine the research design structure and explain the research methodology that was employed in this study (i.e. strategies and techniques). As well as, the chapter defines the obstacles which limit research in its objectives. Data sources and data collection tools are the other part of this chapter that will be discussed.

This study is carried out in two phases (risk evaluation and mitigation). Both phases have same research approach and method that will be expressed in this chapter.

In the first section of this chapter, the research's objectives and questions will be restate to make more clear what is the aims of this study. The second part is a section that will mention the research design and structure, the limitations and obstacles that made to choose this research methodology. "Data Collection" is the next section that will explain about the employed tools and techniques to gather data. "Method of Data Analysis" is another part that will mention the approach and data analysis method and also the data analysis software. At the end, there is a summary section to review the chapter.

3-2 Research Objectives

As mentioned in chapter two (Literature Review), most of the studies were conducted in the United States and some other countries such as Span and Thailand that have their own climate, policy and regulatory related to the renewable energy and also solar energy. The difference in regulatory and weather conditions between these countries and the UK is the driving force to carry out this research according to the UK's policy and climate.

Since the solar energy and especially photovoltaic systems are a novel technology that still are in progress, it is necessary to undertake a research according to technology, policy and regulatory, and conditions in 2013.

Although there are some relevant studies in the UK, but most of them are generally associated with all types of the renewable energy that makes the necessity of doing a research in PV projects more obvious.

The objective of the research is to identify and evaluate risks that can influence the process of a photovoltaic project and operation, also investigate the strategies that can mitigate the identified risks. As mentioned in chapter two, there is a framework for implementing PV projects; this research tries to evaluate the risk of each phase in this framework to understand which phase have a higher rate of the risk. In order to achieve the study's objectives, we should answer the following questions:

- ✓ How is evaluated the rate of the risks in the process of a photovoltaic project's phases according to the UK climate and policy?
- ✓ What measures and strategies can help to mitigate the evaluated risks of the each phase in accordance with the UK climate and policy?

3-3 Research design

Methodology is an important part of every research that shows the study approach which is employed to conduct a research. One of the crucial elements in the research methodology is the research design. Research design is a blueprint for carrying out the research that aids in controlling over parameters which can interfere in the validity of the findings (Burns and Grove, 1997). Polit and Hungler (1999) express, there are many types of research design depend on the flexibility of the research's structure, limitations, and obstacles. Two of these structures are quantitative research and qualitative research. Quantitative research is a type of research method which explains phenomena via numerical data. In this type of research, phenomena's characteristics are investigated to show how something is distributed in a certain population. Qualitative research is associated with developing explanations of phenomena. This type of research tries to investigates why, how, when, and where something occur. The most of

quantitative studies are highly structured in terms of research design whereas the qualitative researches are more fluid.

This study employed the quantitative method in the both phases (i.e. risk evaluation and risk mitigation). Therefore, data were collected by a structured questionnaire which has two sections in order to identify the range of risks in each phase and their solutions.

According to Burns and Grove (1997) questionnaires have some clear advantages versus an interview methodology such less expensive and easier to administer. Robson (2011) mentions, the efficiency of the mailed questionnaires are extremely more than electronically way. Hence, a questionnaire was chosen as a data collection tool.

Also, there were some obstacles during the collecting information that made to choose the selected research method and data collection tool. Some of them are:

- Short time of research: Johnson (1998) states that qualitative research methods are typically slow and quantitative research are faster. Because of this feature and the short time of the research it was better to choose quantitative method. Hence, a quantitative research method was employed with a questionnaire as data collection tool.

- Summer time: because of the summer time, some of the managers and relevant authorities were on holiday and were not available for interview. The best way to contact them was to send them the questions by email and give them the questionnaire.

- A busy period of time: some managers mentioned that they are so busy and preferred questionnaire rather than interview because normally interviews take time more than questionnaires.

- Privacy policy: some companies because of some reasons such as privacy policy and competition market were not interest to give information in

detail via an interview to explain their approach. They prefer a fix questionnaire with specific questions.

- Limited Market: The solar energy is still a new technology that many of people do not have enough knowledge about that and also the solar energy market is not an extensive market. Therefore, the number of the solar company which were interested in cooperation was limited. Hence the research population was limited.

Because of these reasons, a quantitative research method was chosen and designed a questionnaire survey instrument to evaluate the range of the risk in each phase of the PV projects and efficient strategies to cope with these risks in the UK. The survey followed two purposes; the first one was to evaluate the rate of risks during PV projects' phases in the UK and according to the UK's policy and climate in the view of the solar companies and their experts and the second one was to investigate the measures and strategies that can mitigate the effect of the identified risks again according to the UK's policy and climate in the view of the solar companies and their experts.

3-4 Data Collection

Data collected through primary and secondary sources. Primary data collection was done via questionnaire and secondary data covered previous surveys, government publication, and technical document.

There are many strategies in a quantitative research that can be employed to collect data such as interview, questionnaire, and observational tools. One of the most common data collecting instruments is questionnaire. Questionnaires can post or be administered in face-to-face interview or via phone (Polit and Beck, 2006). Because of the limitation, it was more logical to employ a questionnaire as the data collecting tool to ask the questions.

Also, because of mentioned limitations above, this study had to use some secondary data. According to Boslaugh (2007), secondary data is a type of data which collected by other sources. Secondary data is utilised when obtaining the primary data is impossible.

Gaining some information and data for this research needed contacting directly to project managers and solar companies' experts via interviews that none of them accept an interview. For this reason, the secondary data was collected from some previous surveys.

3-4-1 The Questionnaire Structure

In this research, the questionnaire items were developed as a result of an analysis of previous studies and researches relevant to identified risks in the renewable energy projects in the UK and solar energy projects in other countries such as United States. The questionnaire asked to add any other risk that there is not in the questionnaire at the end of the each part. Reliability is one of the important features of the questionnaire design. According to Suskie (1996), a valid and dependable questionnaire elicits consistent responses. Although it is difficult to develop, it is reasonable to design a questionnaire that approaches a consistent level of response.

Leary (1995, pp.81-82) offers seven tips for designing a reliable questionnaire:

1. Precise terminology in the questions can give a real perception to the respondents. Ambiguous can cause misunderstanding in the goal of the question.

2. Avoid using difficult words and jargon, unnecessary and cumbersome phrases make the questionnaire more understandable.

3. Avoid making unwarranted assumptions about the respondents.

4. Conditional information should precede the key idea of the question.

5. Avoid using double-barrelled questions. Double-barrelled questions are a type of questions that ask more than one question but provide the respondent with the opportunity for only one response.

6. Having an appropriate space for answer make the questionnaire more practical and friendly.

7. Pretesting the questionnaires before giving them to respondents can clear the mistakes and deficiencies.

In designing the questionnaire, these criteria were considered to have a valid and reliable survey in order to gather correct and useful data.

The questionnaire consisted of two parts. In the Part A (Appendix A), the questionnaire asked to rate the range of risks in the defined phases of the PV projects. These phases were obtained from previous literature that mentioned in Chapter 2. The goal of the part B was to evaluate the rate of the each phase risks. In the Part B of the questionnaire (Appendix B), two questions were designed to ask about measures and strategies that can mitigate and control the risks of the project phases. In this part the project phases' risks divided into two parts, financial risks and technical, operational, and construction risks. The objective of the Part B was to investigate the strategies that are employed to control PV projects' risks.

With all questionnaires, a paper as the cover sent to companies to explain the objectives of the study and the context of the questionnaire (Appendix C). These explanations can make the objectives of the research more clear.

The questionnaire was given out to the solar companies during June and July 2013 by mail and email. As expected, some companies did not show any reaction. Few of them answered that they did not have any interest to participate in this research for some reasons as mentioned previously. In July 2013 for the second time, the questionnaires were sent to some other companies and to those companies which did not show any reaction. Some of them replied the questionnaires. It almost three weeks took time to collect all questionnaires.

The data has been updated and recorded gradually in the Microsoft Excel spreadsheet with the code sheet that created in the questionnaire (i.e. high risk, medium risk, low risk, no risk, and don't know). This code sheet

measures the tendency from the data of research results. The answer of each question has been allocated with numerical values for the data analysis.

3-5 Data Analysis Approach

One of the most significant sections of any study is the planning process of data analysis. The process of the statistical analysis plan should not be delayed until after have all data in hand (Thompson, 2007). Therefore, the analysis of the data started immediately after collecting the first questionnaire. At the beginning of the August when all the questionnaires were received, data analysis in the quantitative research finished.

The descriptive data analysis chose to analyse the collected data. According to Thompson (2007), descriptive statistics are a type of data analysis that is numerical. It means numbers summarise the data with the purpose of describing what occurred in the sample or population. Also, descriptive data analysis can help researchers detect sample characteristics that may influence their conclusions. Normally in the descriptive analysis, frequency distribution tables use to sort the data as the first analysis and they are a valuable method for describing data. Hence, the data sorted in the frequency distribution, the percentage frequency distribution, and cross tabulation table.

Cross tabulation analysis was the other method that was employed to analyse collected data. Cross tabulation is a method of data analysis in tables and is also called contingency table analysis. This method deals with analysis of tabular data, which implies analysis of categorical variables (Garson, 2012).

To present data bar graphs were employed to show the tendency of the collected data. These tasks did by Microsoft Excel 2010 to sort the data and draw the tables and graphs.

3-6 Summary

This chapter explained about the objectives of the research. This study carried out to rate the range of risk in the each phase of the photovoltaic projects and try to find some strategy to control and mitigate the identified risks.

The second part mentioned the method of the data collection. A qualitative research that uses primary data by employed questionnaire as the data collection tools. Because of some obstacle and limitation, the research use secondary data to cover all needed information.

Then, the chapter specified the structure of the questionnaire and explained about criteria that were considered in designing of the all parts of that.

At the end, the data analysis approach was the last part of this chapter to give brief information about the next chapter “Data Analysis” and the data analysis approach.

Chapter 4: Data Analysis

4-1 Introduction

The methodology that was described in the chapter three, explained the baseline of data collecting. In the Data Analysis chapter, the result will be presented according to the data that was gathered by the structured questionnaire.

In the first section of this chapter, the data analysis method and the way of the presentation will be explained. The second part is a section that will mention the process of the data collection. The main result and interpretation is the next part that will be presented the data by tables and graphs that were sorted via Microsoft Excel 2010. The second part of this section is data interpretation that explicates the result. At the end, there is a summary section to review the chapter.

4-2 Method of Data Analysis and Presentation of Data

Jaggi (2011) explains descriptive data analysis summarises collected data in an easy and understandable way by a numerical and graphic procedure. This is a method that is used in quantitative research to analyse and present the findings. In order to show the result of the collected data via the questionnaire, the descriptive data analysis chose to describe which phase in the process of a PV project is more risky and try to evaluate the risks in the PV project according to the gathered data. Investigating the measures and strategies that can mitigate and control the risks is another task that was considered. This task can help to find which of the measures that were mentioned in the previous studies are practical in the UK and try to find any other strategy.

The following approach will be employed to analyse data: cross tabulation analysis, frequency distribution and percentage frequency distribution, and bar charts. To show the distribution of the data in the first part, cross tabulation data analysis was chosen. Cross tabulation is a method of data analysis in tables that deals with analysis of tabular data, which implies analysis of categorical variables (Garson, 2012). Katzer et al. (1998) explain,

a frequency distribution is a table that demonstrates how each value of a variable frequently occurs in a set of scores.

As mentioned, after summarising and present the data, interpretation of the result is the main objective of this chapter. This part can help to make the result clear.

To present the data and analyse them, the Microsoft Excel 2010 was employed to sort and summarise the data on tables and draw the necessary graphs. Cross tabulation is a function in Microsoft Excel that was used to analyse data.

4-3 Data Collection Process

As mentioned in the research limitations section, the numbers of the solar companies are limited. It can be because of some reasons, such as:

- ✓ The photovoltaic systems are still a new technology and most of the people do not have enough knowledge about the PV system and its applications.
- ✓ Because of the lack of sufficient knowledge of the technology between the users, the market for these systems is not very wide.

Hence, the questionnaires were sent to the 34 solar companies in two stages. For the first stage, the questionnaires were sent to the 20 companies by the post and email in Jun 2013 and after two weeks, only 12 responses were received. In July 2013, the questionnaires were sent to those eight companies that did not show any reaction for the second time and also, the questionnaires were sent to six new companies. In total, the numbers of 19 replies were received until August 2013.

4-4 The Main Result and Interpretation

4-4-1 The main result of the Risk Evaluation

The first part of the questionnaire (Part A) was a question to assess the range of risks during the process of each phase in the PV project. This range

sequence is: high risk, medium risk, low risk, no risk, and don't know/not applicable. We put the six phases of the PV projects process in the questionnaire and asked respondents to rate them in terms of risk. At the end of this part asked to specify any other risky process that is not in the questionnaire. This question can helps to identify which stage are more risky. The designed question was:

- How high or low do you assess the risk of each of the following phases in the process of the PV projects?

All respondents answered the question and only one new risk was received. The risk was related to the change in tariffs and power price and this risk was considered in the permission and regulation phase.

To show the frequency distribution of the collected data, the answers sorted in a cross tabulation table to give a clear image of the data that gathered from solar companies and their experts. In the Table 4-1 you can see the frequency distribution of the risks in the PV project's phases.

Count of PV Project Phases	Risk Rates					
PV Project's Phases	High Risk	Medium Risk	Low Risk	No Risk	Don't Know	Grand Total
End-life & Decommissioning	5%	21%	32%	26%	16%	100%
Business Plan & Financial issues	21%	63%	16%	0%	0%	100%
Installation & Testing	26%	53%	16%	0%	5%	100%
Operation & Maintenance	16%	47%	32%	0%	5%	100%
Permission & Regulation	10%	42%	26%	11%	11%	100%
Planning & Designing	10%	53%	32%	5%	0%	100%
Grand Total	**15%**	**46%**	**25%**	**7%**	**6%**	**100%**

Table 4-1: The cross tabulation table of risks rate in the PV projects' phases

The first column in left shows the phases and next columns indicate the percentage of each risk range. The "Grand Total" row shows the total percentage of the risk in each range.

The table indicates that PV projects have a medium rate of the risk with 46%. This percentage shows the significance of risk management in the

photovoltaic projects because it can be concluded that the PV project are a medium risk project which need to have a strategy to control their risks.

Only 15% of the respondents believe a PV project is a high risk project and 25% assessed these kinds of the projects as low risk. "Business plan and financial phase" with 63% of the medium risk range is the riskiest phase and "End-life and decommissioning" phase has the lowest rate of the medium risk (21%). Also this phase with 26% of the no risk is the safest part of the project. On the other hand, "Don't know" has 16 per cent of the responds that show there an ambiguity in this phase. It can have some reasons; one reason is the life cycle of a PV system is about 25 years and none of the solar companies have experienced the "End-life and decommissioning" phase. It shows there is an uncertainty and ambiguity in this phase.

After "Business plan and financial phase", "Installation and testing phase" has the highest rate of the medium risk with 53 per cent. Technical changes and failures during operation are such reasons that increase the risks rate in this phase. Installation and operation phases' risks have a direct impact on the financial part of the project.

None of the phases have a high risk range in the process of the PV project. End-life and decommissioning with 5% has the minimum rate of the high risk. In contrast, Installation and testing phase with 26% has the maximum rate of high risk between all phases. All the phases except End-life and decommissioning assessed as a medium risk process. Although the percentage of the risk rate in End-life and decommissioning phase are close to each other but this phase with 32% be assessed as a low risk process.

The Interpretation

The result indicates that the major risk is associated with financial and business risk. After that, the installation and technical issues are the most significant risk in technical part rather than other phase. Economist Intelligence Unit (2011) states, "the renewable energy projects are often capital-intensive, and are typically highly leveraged, with up to 70-80% of

the project total being financed through debt". Because the photovoltaic technology is expensive and investing in this kind of projects needs almost a large amount of capital, this issue raises the rate of the financial risk in the PV projects.

Some investors do not have this budget or they do not interest to invest this amount of money by personal finance and they decide to fund. The loan can increase the rate of the financial risk in the project. Financial risk has some aspects, including raising the capital needed to fund the development of the project, and covering interest payments on debt in the project's initial years of development and operation.

Although these phases are separate from each other and some of them have less risk rather than the other, but we should not lose sight of the fact that a risk increase in each phase can affect other phases and the efficiency of the project. It can have an adverse impact on the financial success and put the project at risk. Any interruption in the system operation because of technical problems reduces electricity generating and it means reduction in the revenue. This issue can cause problem in covering interest payments on debt and put the project at financial risks.

Second major risk in non-technical phases after financial issue is change in regulatory and government policy that can influence on success of the project. Governments as the main supporter of the renewable energy projects and especially solar energy projects play a major role. Government as the reference of the power price have the influential role in the market. Every change in the roles, regulatory, and policy can increase the risk of the PV project unless these changes make in order to improve the solar energy efficiency. According to Standard & Poor's (2012) one of the three main rating agencies, the governmental support and subsidies can help solar project to cope with financial issues and every change in supporting policy and regulatory can cause problem.

According to the survey respondents, 11% rated permission and regulatory risk as a high risk and 42% of respondents classify this risk as a medium risk, whereas 26% believe that it is a low risk process.

Installation and testing phase risks arise out of the technical parts such as modules, inverter, and other technical components. Also, this risk is relevant to the quality and experience of the installation company and their experts. 26% of the respondents rate this risk as a high risk process that this range has the most amount of the high risk in all phases. 53% classify installation and testing phase risks as the medium risk process.

All in all after analysing collected data by the Part A of questionnaire, it became clear that the major risk happen in the financial and business plan phase and after that installation and operation phase. It means project managers in solar companies should focus on the financial and technical risk while they do not forget the significance of other risk.

4-4-2 The main result of the Risk Mitigation

After risks rates evaluation, the second measure that should be considered is mitigate the identified risks. In the Part B of the questionnaire, two questions designed to ask about the measures which solar companies take to cope with the photovoltaic projects' risks. These strategies gathered from previous research to investigate how they can help to control the risks according to the UK conditions. At the end of the questionnaire, asked respondents to add any other strategy which would be useful in risk mitigation. The following questions asked:

- What measures can be taken to mitigate financial risks associated with PV projects?
- What measures can be taken to mitigate technical, operational, and construction risks associated with PV projects?

The questionnaire asked to select all that apply. Because of the significance of financial risk, was tried to focus on this issue in one separate question.

Also, because there are some technical measures that they have common impact on the operation and construction, these factors were considered in one question. The result sorted in the following frequency distribution tables:

Strategy		
Surety bonds	10	53%
Insurance	10	53%
Secure contracts	8	42%
Reserve accounts	5	26%
Cross-Collateralization	9	47%
Other measures: Feed-in-Tariff Scheme	15	74%

Table 4-2: The percentage frequency distribution of the financial risks strategies

As can be seen in the table 4-2, "Surety bond" and "Insurance" have 53 percentages of the risk mitigation strategies. According to the UK Ministry of Justice (2012) surety bond is a kind of contract between three parties. One party as "the surety" guarantees that another party as "the obligee" meet the contractual obligation for "the principal" as the primary party. The surety promises to pay the amount of bond as compensation to the principal if the oblige cannot meet the guaranteed obligations.

This can be an appropriate strategy that helps the PV projects to become less risky. In the PV projects, the surety can be a sponsor or a surety company, the solar company is the obligee and the principal is the owner or investor. This contract can help owners to be surer about their investment and reduce the level of the financial risk in the project.

"Secure contracts" is another strategy with 42% that can help to control and mitigate risk. Secure contracts with counterparties can assist to insulate from risks and losses. This strategy can help "Surety bond" strategy more efficient. A secure contract which considers all aspect of the project and its possible problems will increase the efficiency of the surety bond.

Another strategy with 53% is “Insurance”. According to the Thompson (2011) the president of the Rosenberg & Parker insurance company, the main difference between insurance and surety bond is that the insurance is a two-party contract whereas the surety bond is a three-party contract. There is an insured and an insurer and a group of losses that the insurance cover them.

Catastrophic insurance is a kind of insurance than can protect the operation of the system against accidents such as earthquake, flood, etc., this accidents impact on the system equipment and the efficiency of the system and put the project at financial risk. Also insurance can cover the risks and losses of any delay or late project completion. Another problem that can put the system at risk is equipment and performance failure. Warranty insurance can cover these losses and compensate the possible losses.

According to Speer (2010), the Cross-Collateralization is a technique that is arranged between owner and solar company to hedge against product shortfalls. It can be as a strategy to mitigate financial risk of the PV projects. In this case the equipment is used as collateral for the mortgage.

The last strategy in the questionnaire was reserving an account that has the least percentage in all financial strategies. This strategy states that it would be beneficial to have an amount of money as backup budget to cover the delays and losses during the project. It is possible some losses happen that the insurance would not cover them; this account can compensate the losses. Also, normally the process of the losses covering by the insurance companies takes time, during this time the reserve account can back up the project. Only 26% of the respondents agreed with this financial strategy that shows it should not be a priority to choose the reserve account as a financial strategy but it still can be a choice.

In the questionnaire, there is a part that asked respondents to specify if there is any other strategy and plan which is not in the questionnaires and can control the risks. 74% of the solar companies suggested a financial plan

in the name of 'Feed-in Tariff Scheme' that can help to control the PV projects financially.

According to www.gov.uk 'Feed-in Tariff' (FIT) is a programme that if you generate your own electricity by solar or wind energy, the energy supplier will pay you money. This scheme was run on April 2010 by the UK government to encourage and support owners to invest on renewable energies. The power companies pay the generating tariff for produced electricity via solar panels to occupier whether the electricity is used or not. If the occupier generate the electricity but do not use it and send the generated electricity to the national grid, the power company will pay for the generated electricity and also for the amount that export to the grid.

FIT scheme helped solar companies to create a new service in the name of "Free Solar Panels". Solar companies borrow the necessary money from banks to cover the all costs of the project include installation, maintenance, etc. and the generating tariff pays back the loan and the company's profit (http://ashadegreener.co.uk/?ad_ref=g4&gclid=CMSrrdHf8rgCFQTMtAodgX4A7w, No Date).

This idea can make a great progress in PV project. In this scheme the financial risks reduce to zero for the householders. They do not need to invest any money in the project that can encourage them to use solar panel for generating their own electricity. As mentioned before, one measure for increasing financial risks can be sharing the risks between different parties such as insurance companies. This service exactly does this task; there is no financial risk on the owners in this strategy.

All in all, all these financial strategies can be helpful to control and mitigate the financial risks in a PV project. The "Feed-in Tariff" strategy that solar experts suggested in the questionnaire (74%) may be the best plan to control financial risks in the UK. The Figure 4-1 shows the percentage of the each strategy to mitigate financial risks.

Figure 4-1: Financial risk strategies in the PV projects

The last section in the Part B of the questionnaire was a question related to operational, construction, and technical risk in the photovoltaic projects. The objective of this question was to assess the existed strategies related to the technical risk. The question designed to ask about the strategies relevant to technical phases and the result sorted in the following frequency distribution table:

- What measures can be taken to mitigate technical, operational, and construction risks associated with PV projects?

Strategy		
Weather and climate data analysis	11	58%
Site location analysis	9	47%
Proven technology and vendors selection	10	53%
Warranty insurance	12	63%
Additional quality test	4	21%
Careful selection of engineering, procurement, and construction firm	8	42%
Independent engineer to assess the project's contracts, construction, technology, system design, etc.	7	37%

Table 4-3: The percentage frequency distribution of the technical, operational, and construction risks strategies

Also the Figure 4-2 shows the result of the technical, operational, and construction risks strategies in the following chart:

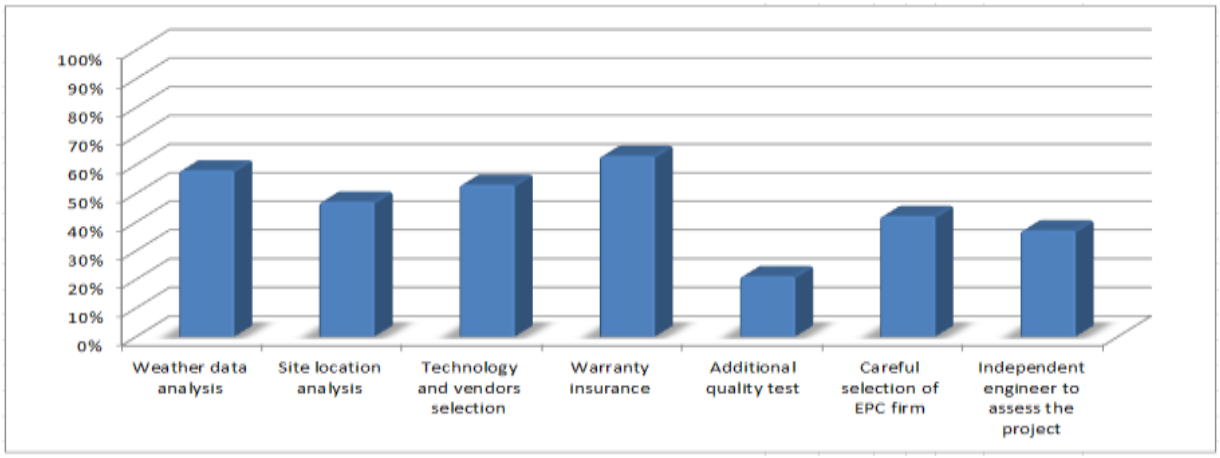

Figure 4-2: Technical, operational, and construction risks strategies in the PV projects

The highest percentage in this part (63%) belongs to "Warranty insurance". One of the major problems during operation of a PV system is interruption in system performance. It can be because of some technical problem such as equipment malfunction. A good warranty that can cover the technical problems and accidents is one strategy for preventing losses and risks. Technology and equipment accessibility, fast reaction, and updated experts are such criteria that should be considered in choosing a warranty service.

Weather and climate data analysis is the second strategy with 58%. The most important thing in "Planning and designing phase" is to have clear and real image of the location and conditions. The base of the PV system design is weather conditions and sun radiation. Collecting the weather data from the trustable sources and having an appropriate analysis of the gathered data can increase the efficiency of the PV system and reduce the financial and operational risks. Also the weather data history at least for ten years can help to have an accurate analysis.

Selecting a proven technology and vendor is another measure with 53%. The used technology and materials in solar panels production process plays a prominent role in the efficiency of the modules. Choosing reputed vendors

who sell a proven technology and equipment can prevent from some losses and risks. Because the solar panels and other equipment are the body of the system and most of the costs are related to these equipment. Also these panels generate electricity and revenue. As a result, the company which is chosen to implement the project have a significant role and having a plan for selecting the company should be one of the strategies which can mitigate risks.

The real perception of the site is another parameter that can control risks. The geographical location, climate, and surrounded buildings, trees, etc. which can make shades should recognise and find some solution for them. Site location analysis is a measure than cover all these tasks and should be employed to mitigate risks.

"Careful selection of engineering, procurement, and construction firm" with 42% and "Independent engineer to assess the project's contracts, construction, technology, system design" with 37% are other strategies which can control risk. Independency of the engineer who assesses the project is important. Some engineers have contract with company and because that they recommend their technology and expertise.

The last strategy is "Additional quality test". After employing all measure the last one can control the risk is to do some test in order to check the quality of the equipment, company, expert, etc. But this measure increases the costs and also needs the expertise for doing this measure. Because of these reason this strategy should be the last one that is chosen.

4-5 Result

In comparison with the previous research, there are some common and different results in this study and previous literature. As mentioned before, in the research related to the renewable energy sources that carried out about all type of the green energies, the major risk is related to the financial issues. This is exactly the same result that was obtained during this study. It shows the main issue in the PV project and also all types of the renewable

energy sources is financial problems and risks that can increase the risk of the project.

Although the result that can help PV project managements to mitigate the financial risk in this study is not in contrast with other research, but the main suggested measure is completely different. As mentioned in the literature review chapter, in the most research related to financial risk mitigation in PV projects, the best solution for financial risks is insurance. Most of the these studies carried out in the United States whereas according to the UK government policy and regulatory, the best solution for the financial problems in the UK can be Feed-in Tariff programme that government ran to support PV projects.

On the other aspect of the research, the strategies that investigated as the appropriate measures for risks mitigated more or less are the same in compare with the other research.

4-6 Summary

This chapter presented the result of the data. It explained about the method of the data collection, the tool was employed to collect data and the data analysis approach. The result presented by the cross tabulation tables and graph bar to make them clear. In continue, the data interpreted and in the last section the findings compared with the previous studies for consistency, and evaluate the significance of their findings.

Chapter 5: Conclusion and Recommendations

This final chapter of the research will re-state the problem. Then, it will review the methods of data collection and analysis that were employed in this study. The major section of this chapter is related to summarise and discuss the result to answer the designed questions according to the findings. The recommendations section is the last part of the chapter that tries to suggest some recommendations based on the findings to answer the questions.

5-1 Statement of the Problem

As mention before in the introduction and methodology chapters, the solar energy is a novel technology that is still on progress. The implementation of such projects needs an approach and framework according to the last changes. Hence this study followed the previous research to investigate their framework

Another parameter that should be considered in the solar projects is that the characteristics of the location. Every country has its weather conditions according to their own geographical location and climate. The policy is made according to these criteria. Therefore, although the previous research that was carried out in other countries can be useful for other countries but carry out a research according to the UK's policy and climate was necessary.

The gap in the previous research was that the research which conducted in the UK are related to the all types of the renewable energy whereas solar projects have some characteristics that can make differences. Another point is that there some studies relevant to solar energy but most of them carried out in other countries whereas there are some regulatory and policy beside the climate in the UK that can make some differences.

5-2 Review of the Methodology

This research employed a quantitative research method to achieve its objectives. The study included two parts; first section was associated with

evaluation of the risk's rate in each phase of the PV project and the second part was related to the investigation of the strategies and measures that can mitigate and control the risks. In both sections a quantitative research method were chosen. This numerical research approach can create a good understanding related to the results.

Also, there were some limitations and obstacles during this study that forced into choosing a questionnaire as the data collection tools. The questionnaire designed base on the previous research. The questionnaire designed to collect data in two parts from solar companies.

The descriptive data analysis was chosen as the research data analysis method to analyse the gathered data and Microsoft Excel 2010 was employed to sort the data by cross tabulation, frequency distribution table, percentage frequency distribution, and bar graphs. Descriptive data analysis describes the main features of the data numerically.

5-3 Conclusion

As mentioned before, the role of the renewable energy in the future of the energy supply is undeniable. Solar energy is one type of the renewable energy that can be used in every building to supply the required electricity of the residents by photovoltaic system. This is safe, free and there is no pollution.

One of the influential factors in this type of projects that can prevent projects from success is risks that may occur during the PV projects. Therefor identify and evaluate risks of the project and the range of each one was the first necessary measure that was considered in this research. According to the findings and analysis of the collected data, implementation of a PV project has a medium rate of the risk. Majority of the respondents evaluated the project phases as a medium risk. It means, the risk have direct bearing on the result of the project. These findings met the first designed question that was related to the identification and evaluation of the risks in each phase.

"Business plan and financial issues" and after that "Installation and operation phase" have the highest range of the risk between all six phases. Hence, it became clear that the concentration of the risk mitigation should be on the financial risks and then the technical risks and problems. The cost of the equipment is high and this matter increase the financial risk. The technical problems that can cause some issues in the life cycle of the project are another second factor which increases technical and financial risks.

Some measures suggested to respondents according to the previous research and between all of them the warranty insurance and then weather data analysis had the highest rate of response. It means, in financial risks, surety bonds and insurance were the top strategies than can control financial risks. But 74% of the respondents suggested a strategy that seems it can be the best strategy to mitigate the financial risks. "Feed-in Tariff" scheme is a programme that is implemented by the UK government and controls the financial risk and lead the PV project towards success.

The UK government in order to encourage and support owners ran this programme and pay moneys directly to households who generate their required electricity. It means, they generate electricity and use it and receive money because of that and also they do not need to use from national grid. The result is that they do not spent money on electricity bill and on the other hand the money that the government pay can cover some part of their PV project's costs.

The solar company based on the Feed-in Tariff scheme ran a program "Free Solar Panel". In this programme, they borrow the necessary money from banks to cover the all costs of the project and the generating tariff pays back the loan and the company's profit. It can be the best strategy for owners. They use equipment and electricity for free and do not need to invest any money in the project.

In terms of the technical risks some measures were rated by the survey respondents. The highest responses belong to "Warranty insurance" and "Weather data analysis". Warranty strategy can cover any interruption as soon

as possible. Because any interruption can prevent from generating electricity and it means no income and increase the rate of financial risk.

Having a right interpretation of the site situation and climate can help to choose the best equipment according to the needs of the house. Hence "Weather data analysis" can assist to have the correct interpretation and analysis of the sun radiation.

All in all, the growing number of the solar companies places the solar energy as the centre of the business strategies. Operational, political, regulatory, and financial risks and macroeconomic uncertainty are the consequences of the PV project implementation. The UK government try to cut back on support for solar energy projects via legislating rules and running some programmes. At the same time, solar companies employed some tools such "Free solar panel" service to control and mitigate risks and encourage householders to use PV systems. It seems, as long as Feed-in Tariff scheme runs, this strategy can be the best measure to control the PV projects' risks.

5-4 Recommendations

The result of the research respondents' experience and their insight as the solar energy experts that were collected for this study, pointed some recommendations for the implementation process of the PV projects.

There are many parties in implementation of a solar project (i.e. PV industry building sector, energy sector, public, government, financial sector, insurance, etc.). The first priority should be the risk reduction and mitigation. The risks focus should transfer from the owner to the other parties to encourage them invest in solar photovoltaic systems. For instance, the Feed-in Tariff programme can help to achieve this objective. Also, the insurance companies can accomplish this objective to help companies and owners transfer the risk from investor to other parties. The Free Solar Panels scheme completely transfers risk from owners to other parties.

The second measure than can help to mitigate risks is warranty and backup service that is one of the key factors in risk mitigation in operation phase.

Maintenance, spare parts, and mending are such measures that need a strong updated experts and technology to prevent projects from risks and losses. They can control any interruption during the system operation and reduce the losses and damages results.

Collaboration between stakeholders is another recommendation for mitigating risks. For instance, weather data play a prominent role in the success of the PV projects. Weather data collecting is a process that needs collaboration between solar companies and weather stations. Also solar companies should collaborate with insurance companies to run some especial plan and programme for solar systems.

Keeping update the solar experts and stakeholders according to the last technology changes and government policy can help to design, implement, and maintenance an efficient system. Lack of knowledge and experience amongst stakeholders can cause technical and financial risks.

5-5 Summary

In this chapter the research objectives reviewed and the methodology, research structure and data analysis approach mentioned.

The conclusion was the other part of this chapter that review the result and tried to answer the research questions by the findings.

Recommendation was the last part of this chapter that recommend some solutions and measures according to the result of the findings that can help PV project to control risks and walk towards success.

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Appendices

Appendix A: Questionnaire

PART A

- How high or low do you assess the risk of each of the following phases in the process of a PV projects? (4=high risk, 3=medium risk, 2=low risk, 1=no risk, DK=don't know/not applicable)

	4	3	2	1	DK
Planning and designing phase					
Business plan and financial issues					
Permission and regulation phase					
Installation and testing phase					
Operation and maintenance phase					
End-life and decommissioning phase					

Other risk, please identify:

Appendix B: Questionnaire

PART B

- What measures can be taken to mitigate financial risks associated with PV projects? (Select all that apply.)

Surety bonds (between lenders and developers)	
Insurance (between lenders and developers and third party)	
Secure contracts with counterparties to insulate from risks	
Reserve accounts to cover production shortfalls	
Cross-Collateralization of a Portfolio of Projects	

- What measures can be taken to mitigate technical, operational, and construction risks associated with PV projects? (Select all that apply.)

Weather and climate data analysis	
Site location analysis	
Proven technology and vendors selection	
Warranty insurance	
Additional quality test	
Careful selection of engineering, procurement, and construction firm	
Independent engineer to assess the project's contracts, construction, technology, system design, etc.	

Other measure, please specify

Appendix C: Questionnaire Cover Page

Dear participant,

You are invited to participate in a research for the Master's Degree of this researcher. The study is about domestic photovoltaic systems. The research tries to identify and evaluate the risks in the lifecycle of the PV projects. The second objective is to try to find the measures and strategies that can control and mitigate identified risks.

As the photovoltaic experts, your opinions are very valuable for this research. You are requested to complete a questionnaire designed in two parts to obtain information.

First part wants you to evaluate the rate of the risks in each phase of a PV project and add any other idea in this part. The second part asks you to select each of the suggested strategies that you agree that they are capable to control the risks. At the end, the questionnaire asks to add any other strategies which can help to mitigate risks.

It is noteworthy to mention all the information will keep safe and do not share with any other people.

Thank you for your assistance.

Sincerely,

Milad Atigheh Chian